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INFORMATION OBTAINED FROM AIRPLANE FLIGHT TESTS
IN THE YEAR 1927-1928

By W. Hübner

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S u m m a r y

The information obtained from airplane flight tests in 1927-1928 covers chiefly the effect of the structural features of an airplane on its stability, controllability, maneuverability and spinning characteristics.

Synopsis of Flight Tests from 1925 to 1927

In 1925-1926 the flight tests of new airplanes by pilots of the D. V. L. (Deutsche Versuchsanstalt für Luftfahrt) were not included in the type tests. Although various airplane types were occasionally flown by pilots of the D. V. L., the chief purpose of such flights was the gathering of general information on the characteristics of German aircraft, which might form the basis of the tests contemplated for the following year. No scheme for the testing of these characteristics had yet been evolved, nor did there exist any definition of them nor any distinction between flight characteristics and performances.

*"Erfahrungen bei Flugeigenschaftsprüfungen im Jahre 1927-28," from Zeitschrift für Flugtechnik und Motorluftschiffahrt, April 29, 1929, pp. 189-195. 130th Report of the D.V.L. Flight Section.

Flight characteristics were defined by classifying the factors which determine them, namely, balance, stability, controllability,* maneuverability** and spinning characteristics. This classification furnished a definite testing program capable of covering all the airplane characteristics. This scheme also included the testing of all the characteristics of an airplane which affect its controllability, such as visibility, engine controls, instrument arrangement, etc.

After thus collecting the necessary data for the determination of the flight characteristics, the testing of these characteristics was undertaken in 1926-27 in conjunction with type tests. At first, these tests could have only a small influence on the characteristics, since no detailed specifications of the requisite airworthiness characteristics yet existed. Thus, no indications were available which might have led to requesting specific flight characteristics from the manufacturers. Nevertheless, the results surpassed all expectations, since the designers had been anxious not only to eliminate defects when they were immediate sources of danger, but also to make voluntarily any changes suggested by the D.V.L. for the adaptation of the proper-

*Controllability is the resultant of the magnitude of the control forces and of the effect of the control surfaces. This effect is determined by the magnitude of the angular velocity about the corresponding airplane axis for a given deflection of the control surface and a given pressure.

**Maneuverability, i.e., the ability of an airplane to move in space (motion of the C.G., not simply rotation about the C.G.), depends on controllability and reserve power. It is therefore a function both of the flight performances and of the flight characteristics.

ties to the purpose of the airplane type considered. Designers were not only willing to assume the risks of the test flights, but they even engaged D.V.L. pilots for test flying and developing new airplanes in addition to making regular type tests. As soon as it was confirmed by experience that the changes made at the suggestion of the D.V.L. were actual improvements of the characteristics and resulted in increased safety, there began, under the directive influence of the D.V.L. tests, a systematic development of the flight characteristics, which had hitherto been almost completely neglected, on the economical side of the problem, during the post-war period. The educational effect of the D.V.L. tests, which gradually became regulations, was evident in the airplanes built subsequent to this period.

During the second half of the year 1926-27 the flight characteristics had to conform to specific requirements which, if not fulfilled, prevented the acceptance of the airplane type considered. These requirements were adopted from the viewpoint of safety and chiefly regarded stability characteristics. In 1927-1928 the requirements which had to be satisfied by these characteristics were gradually raised, since the increasing experience gained in actual operation necessitated further progress.* A stagnation of the regulations in this field is as little to be expected as a systematization of the actual flight tests. 27 different airplane types were tested in 1926-27 for their character-

*See airplane specifications (BVF) Nos 4515 to 4545. The BVF are published by the D.V.L. , from which they can be obtained.

istics and 35 other types in 1927-28. These characteristics were partly developed, on behalf of the designer, before the type test by D.V.L. pilots. The following is a report of the information obtained during the work of development and testing.

Information Obtained from Flight Tests in 1927-28

Balance.— According to the specifications, a transport airplane should be in equilibrium at the impact pressure, with its engine running at approximately 80% of its maximum r.p.m., and with the elevator control released. For a fully throttled engine and unchanged aileron setting, the impact pressure should not be increased more than 10%. Therefore the balance should be only slightly affected by the propeller slipstream. For the usual distances of the propeller axis from the C.G., the moment of the propeller thrust is scarcely appreciable as compared with the moment of the propeller slipstream. Hence, the balance of the high-wing and low-wing monoplanes is similarly affected by reducing the engine speed. The reduction of balance variation is a problem which has not been fully solved. Experience gained in the course of flight tests confirms the fact that elevators with "auxiliary balance" produce greater balance variations than unbalanced elevators.*



*The different methods of balancing are denoted as follows:

- a) Balancing surfaces fitted on the sides of the elevator are designated as "horn balances."
- b) Balance achieved by backward shifting of the axis of rotation is denoted as "internal balance."
- c) "Auxiliary balances" are free surfaces mounted at a certain distance from the elevator.

Elevators with either internal or horn balances behave like unbalanced elevators, if they are correctly designed. Investigations of the impact pressure in the propeller slipstream lead to the conclusion that the differences in balance, due to the propeller slipstream, decrease with increasing static stability. Thus, with improving stability characteristics, we may expect a decrease of the difficulties which arise from balance variations under the action of the propeller slipstream.

It is often difficult to maintain a state of equilibrium with released controls at the impact pressure for which it is required. The calculated impact pressure of equilibrium does not agree with its value in flight, especially in the case of high-wing monoplanes with a central wing portion of great chord and with a thick wing section and in the case of strongly staggered biplanes with a thick wing section. Equilibrium is usually reached at angles of attack larger than those assumed on the basis of calculation. In a general way, the position of the center of equilibrium of the moments seems to be much more affected by the arrangement of the components involved (position of wings with respect to fuselage, elevation of tail surfaces, etc.) than appears from the calculation. However, it is rare that points of moment balance, which, according to calculation, lie within the range of normal flight, shift to inadmissible positive or negative angles of attack under the action of these influences.

There are different means of offsetting such faulty balances

without materially changing the airplane structure. It is often difficult to change the angle of attack of the stabilizer, although this is usually the most obvious means. A simple method consists in fitting a weight balance to the elevator, thus changing the position of this unloaded tail surface and hence also the balance. This means, however, is only applicable to nose-heavy airplanes which require the weight balance to be located forward of the axis of rotation. In the contrary case, this change would cause the C.G. of the elevator to be shifted aft of the axis of rotation, with ensuing danger of tail surface vibration. A change in the elevator balance, i.e., a shifting of the C.G. of the elevator with respect to the axis of rotation, not only alters the balance of the airplane, but also its stability when the elevator is released. Forward shifting of the C.G. of the elevator reduces the static stability.

A still simpler means, which can be used for the suppression of both nose-heaviness and tail-heaviness, consists in bending the elevator (Fig. 1). The elevator portion which is farthest from the axis of rotation is bent slightly downward to produce nose-heaviness and slightly upward to produce tail-heaviness. As in the case of the weight balance, the position of the released elevator is thus changed to fit requirements, and hence the equilibrium is shifted to another impact pressure. The change produces a great effect, so that very slight bends usually suffice. In the case of elevators with horn balances or with chords varia-

ble along the span, the position of the released elevator, and hence the balance, can be changed by warping the elevator surface, so as to cause the balancing flaps or portions of the elevator to form acute angles with the rest of the elevator surface (Fig. 2).

The balance can also be adjusted over a wide range by changing the direction of the slipstream. Thus, tail-heaviness can be eliminated on high-wing monoplanes and biplanes by cutting out the central portion of the trailing edge of the wing, as is usually done for visibility (Fig. 3).

The fear that the cutaway may impair the flight characteristics, on account of the deflection of the lift distribution from the elliptical shape, is not confirmed in practice, since this shape is approximately restored by the propeller slipstream. The induced drag naturally increases during a glide, thereby increasing the angle of glide. Airplanes with a large angle of glide are better suited for landing on small fenced landing fields than those which, owing to a small angle of glide sail very flatly and for a long time. However, attention is called to the fact that such cut-out portions increase the stresses in normal horizontal flight. Thus, the change is only permissible provided the wing is, or can be made, sufficiently strong.

A change in the balance, by the fitting of a tension spring to the controls (Fig. 4), thus altering the deflection of the released elevator, is only permissible when the stability characteristics and the control forces fulfill the safety requirements

even without the spring. Tension springs should be used only to improve airplane characteristics beyond their required minimum value. It would be wrong to rely upon the perfect working of the tension spring for safety. Besides, on several airplane types, defective tension springs caused changes in the direction of the elevator forces during the landing.

The equilibrium of an airplane about its vertical axis is so determined that straight flight should be automatically resumed when the rudder controls are released. With throttled engine the airplane should start a curve in a direction opposite to that with the throttle wide open. The curves should have large diameters. Discrepancies in the position of equilibrium are corrected by the same means which were used in connection with balance about the lateral axis, except for the weight balances. It was found that auxiliary balancing surfaces on both sides of the elevator produced very strong variations of equilibrium for changes in the propeller slipstream.

Equilibrium about the longitudinal axis in straight flight should always correspond to the horizontal position of the lateral axis, the aileron controls being released. Hence, the airplane should not tip. In this connection attention is called to the fact that any warping of the wing, for the purpose of remedying possible defects, affects the spinning characteristics in such a manner that airplanes with warped wings make right-hand spins differently from left-hand spins. In the case of metal airplanes,

the wings of which cannot be warped, the ailerons are bent to compensate for defects.

Stability.-- There should be stability about the three airplane axes when the hands are removed from the controls. In the case of stability about the lateral axis, this condition requires the C.G. to be shifted far forward. While the C.G. of airplane types built prior to 1926 was usually located 40 to 50% of the chord aft of the leading edge, the C.G. of more recent aircraft types is located at 30 to 35% of the chord.

It was even possible to achieve a sufficient stability of airplanes with an unfavorable location of the C.G. Thus, such aircraft types were improved by an increase in the size of their horizontal control surfaces. In this connection a hitherto unexplained phenomenon was observed, which occurred again on another airplane type. When the span of a rectangular control surface was so increased that the added portion produced an elliptical outline, the stability characteristics grew considerably worse. On the other hand, when for the same span the increased control surface remained rectangular, the stability was improved.

The results of longitudinal stability calculations, made in connection with the D.V.L. type tests, are usually in good agreement, as regards stability (existing or not), with the results of flight tests. Whenever discrepancies arose in the past, e.g., when flight tests revealed instability with released elevator, while, according to calculation, stability could be expected under

these conditions, the differences were attributable to wrong assumptions in the calculation (another position of the C.G., incorrect allowance for the elevator deflection, etc.).

In general, no difficulty is encountered in achieving stability about the vertical axis. Possible defects can always be remedied by increasing the size of the fin. Airplanes, the fuselages of which have very large cross sections clear back to the tail, are often unstable even with large fins. This is due to the shielding effect of the fuselage upon the tail surfaces, especially at large angles of attack. This is remedied by elevating the fin.

Little attention was paid to the question of achieving stability about the longitudinal axis with controls released. Even on new airplane types it is seldom achieved. Setting the wings at a dihedral angle is the only means known for improving these conditions. There is often an apparent instability, the effects of which are similar to those of the actual one. Ailerons, especially when balanced, do not fully return to their neutral position when their controls are released, even when the friction is small.

No calculations or results of model measurements as regards lateral and transverse stability are yet required by the D.V.L. in the type tests, so that no comparison can be made in this respect with the results of flight tests.

Controllability.— Even for impact pressures greater than

those of horizontal flight the control forces should be small and require no particular effort on the part of the pilot. Besides, equal deflections of elevator, ailerons and rudder should produce corresponding forces. These conditions can be fulfilled by reducing and harmonizing the control forces.

A reduction of the elevator control forces by shortening the elevator chord results in elevators of large aspect ratio. Such elevators are undesirable, since any increase in the aspect ratio causes an increase of the lift increment with the angle of attack. Hence, the maximum lift value of such elevators is reached at comparatively small angles of attack.

As already mentioned, the use of free compensating surfaces for the balancing of the controls produces large variations in the balance, due to the propeller slipstream. Elevators with free or horn balances are rather dangerous for parachute jumping purposes, since the parachute cords may easily get caught on them. "Internal balances" are another means of reducing the elevator forces. This arrangement, which was introduced at about the same time in Germany and abroad, results in a reduction of about 50% of the control forces for a shifting of the hinge to 24% of the elevator chord. A shifting of more than 30% of the elevator chord causes, for large elevator deflections, changes in pressure with ensuing overbalance.*

Internal balances have also proved useful for the reduction

*See N.A.C.A. Technical Report No. 278, "Lift, Drag and Elevator Hinge Moments of Handley Page Control Surfaces," by R. H. Smith, 1927.

of rudder and aileron forces. In order to retain controllability at large angles of attack, the rudder chord cannot be reduced at will, although, according to previous experience, rudders with large aspect ratio do not affect normal flight unfavorably. The most favorable aileron chord seems to depend on the thickness and camber of the wing-tip section. It could not, for each wing section, be reduced to less than 20% of the wing chord, without reducing its efficiency.

Rudder surfaces with a long trailing edge and a short leading edge (Fig. 5) formed an acute angle at the rear top end and produced great control forces. By rounding off the top corner these forces were greatly reduced without the rudder efficiency being impaired. In some cases the rudder forces can be reduced by horn balances. These are often oversized. The rudders are then overbalanced, the result being a periodical change in the direction of the control forces. This change of pressure often begins only at great flying speeds and may cause tail-surface vibrations if the speed is further increased. Although in most cases the rudders were overbalanced, this may also happen to elevators and ailerons.

Great difficulties were encountered in reducing the aileron forces until balances were used. Not only ailerons with a chord of more than 25% of the wing chord, but also those which were wide in comparison with the wing span, produced excessive control forces. Therefore, ailerons extending over the whole wing span

were not adopted. Free balancing surfaces proved satisfactory since the propeller slipstream did not affect the aileron controls.

The magnitude of the requisite elevator efficiency depends on the use of the airplane type. It should stand in a certain fixed relation to the wing strength. It was not thought necessary to express the requisite strength as a function of the elevator efficiency. This method might have led to the development of slow airplanes. The elevator efficiency of transport airplanes is determined chiefly by their ability to land horizontally, even when empty, their C.G. being in the extreme front position and the stabilizer in that of actual service flight. It is often difficult to fill this requirement, which enables the pilot to make sudden emergency landings without changing the stabilizer setting. This difficulty is chiefly encountered in the case of airplanes with great differences in balance due to the propeller slipstream.

As expected, the ratio of the stabilizer chord to the elevator chord greatly affected the elevator efficiency and hence the fulfilling of the above condition. The effect of the tail surfaces, the fixed portion of which has a chord 1.5 times that of the movable portion, is usually just sufficient. The efficiency of the tail surfaces became insufficient whenever the ratio of the chord of the fixed portion to the chord of the movable portion exceeded this value. The outline of the elevator had also to be considered. Elevators excessively tapered in plan (Fig. 6) pro-

duced absolutely inadequate effects. An ample outline of the elevator is therefore advisable.

The magnitude of the rudder effect must be sufficient to assure good controllability of the airplane when taxiing on the ground, even with a back or side wind. In flight, the action of the rudder must be sufficient to permit of side-slipping in both directions with engine completely throttled and also to enable satisfactory curvilinear flight. The action of the rudder is satisfactory in most cases, except when the fuselage is oversized. The rudder is then shielded by the fuselage and its action becomes inadequate in the turbulent wake of the fuselage. At large angles of attack and especially at angles of attack larger than that of maximum lift, the vertical tail surfaces are shielded by the horizontal tail surfaces. It is therefore advisable to extend at least part of the rudder below the horizontal tail surfaces (Fig. 7). When a portion of the rudder is relieved of the shielding effect of the horizontal tail surfaces, the action of the rudder is satisfactory even at large angles of attack.

In the case of multi-engined airplanes the propeller axes of which lie outside of their planes of symmetry, the rudder effect should not only be sufficient to maintain straight flight if one of the engines fails, but should also enable curvilinear flight in both directions. In general, this condition can be fulfilled without increasing the control forces to such an extent that the use of a balancing tension spring and an adjustment of the fin become necessary.

On transport airplanes, the action of the ailerons must be sufficient to throw the aircraft quickly into the banked position of curvilinear flight and side-slipping, and to balance steep banks due to atmospheric disturbances. The last point is particularly important, since, as mentioned above, there is often no lateral stability and, even when it does exist, the airplane usually returns too slowly to its normal position of flight. On biplanes, the action of the ailerons is adequate when they are only on the upper wing. Of course, better results are obtained when both the upper and lower wings are equipped with ailerons. No adequate effect is produced when only the lower wing is provided with ailerons.

Ailerons extending over the whole span do not produce a much better effect than those which cover only about $2/3$ of the span (Fig. 8). As already mentioned, very wide ailerons produce great control forces. As stated above, no results applicable alike to all wing sections are available as yet regarding the best aileron chord. In many cases ailerons, the chord of which was $1/5$ that of the wing, and even less, gave good results. When the wing section at the tips is very thick as compared with the chord, the ailerons lie in the turbulent wake of the wing, even at small angles of attack, and become effective only at large deflections. The aileron controls then behave as though there were considerable slack. The action of ailerons which were not extended to the wing tips was found to be particularly unfavorable. The portion

of the wing area extending beyond the ailerons strongly retards the rotations about the longitudinal axis and hence considerably impairs the action of the controls (Fig. 9). In 1926-27 such ailerons were used on several airplane types. They have now been almost entirely abandoned.

Maneuverability.— The ability of an airplane to change its attitude rapidly is called maneuverability. It depends both on controllability and on reserve power. Transport airplanes need not have the same degree of maneuverability as training and stunt-flying airplanes. The granting of stunt-flying certificates depends on the ability to perform certain motions in space, i.e., on a certain degree of maneuverability.

A complete rotation about the lateral axis, called "looping," can be made if the action of the elevator is strong enough to enable the attainment of the requisite angle of attack even in curved flight. Since this is usually possible for all airplanes, no particular maneuverability is required for looping. The excess power necessitated by the change in altitude which occurs while looping, can be acquired in the form of kinetic energy during a preliminary power dive. Stunting airplanes, however, must be able to loop without any preliminary dive, from horizontal flight at full engine speed and without loss of altitude.

Complete rotations or rolls about the longitudinal axis can be made in two ways. On the one hand, this turn can be performed by autorotation. To do this, at least one end of the wing must

be in the stalled condition. The motion is then merely a spin about an axis parallel to the horizon. The ability to perform such spinning rolls proves only that an airplane can be thrown into autorotation at large angles of attack, but it affords no indication of its actual degree of maneuverability. The spinning roll is therefore no longer considered a stunt. On the other hand, the so-called "controlled roll," which is another way of effecting a rotation about the x-axis, is an indication of good maneuverability. In this case the airplane remains continually in a state of normal flight and is rotated only by the action of its controls. Therefore good control efficiency, and especially aileron efficiency, is an essential condition for the performance of this stunt. The control forces must also be small, since otherwise the ailerons cannot be fully deflected in the inverted position. Good elevator and rudder action is also necessary to maintain as straight a flight path as possible during the rotation. It can never be absolutely straight, however, since even with much excess power, essential for this maneuver, altitude is lost during the period of the flight when the wings are strongly inclined to the horizon. In using wing sections which produce little lift at negative angles of attack, altitude is also lost in the inverted position. It is therefore preferable to equip stunting airplanes with slightly curved or symmetrical wing sections. Lateral stability is also important for the controlled roll. Airplanes with a dihedral and good

lateral stability cannot be easily brought into the inverted position by rolling. In this attitude they are laterally unstable and tend to return to the normal position of flight, if they are not held by ^{the} controls. It is difficult to make long inverted flights with such airplanes. The degree of lateral stability of stunting airplanes should therefore be very slight. An airplane must have excellent flying ability to perform a controlled roll. Hence, in making this maneuver, an aircraft gives a rather complete idea of its characteristics. The controlled roll is therefore considered the most important maneuver for testing the flight characteristics.

Ordinary rotation about the vertical axis is of no practical importance. Owing to the bank in curvilinear flight, the rotation is not made about the vertical axis alone, and no unusual degree of maneuverability is therefore required. Besides, in most curves flown with maneuverable airplanes, the air and inertia forces are not balanced. Such airplanes are thrown into such steep banks by aileron deflections, that the position of the wings becomes nearly vertical and the curvilinear flight then closely resembles a simple rotation about the lateral axis. Hence, such a curve is somewhat similar to a loop with its axis of rotation perpendicular to the horizon.

In addition to the above-mentioned maneuvers, which are turns about the three axes of the airplane, there are many combined motions. They can be carried out when there are efficient

control surfaces, small control forces, a good agreement between the action of the control surfaces and of the control forces, and sufficient reserve power.

Spinning characteristics.— The tendency of airplanes to start autorotation at large angles of attack can only be considered as a defect of their aerodynamical structure and not as a requirement for any special purpose. The fact that present-day airplanes become transversely unstable and start spins in stalled flight only causes a considerable reduction of safety without affording the slightest advantage. Hence, the trend in the development of airplane characteristics is toward spin-proof airplanes laterally stable in stalled flight. Until this result is achieved, airplane spinning characteristics should be developed so as to enable a quick recovery from the spin when the airplane is high enough above the ground.

In 1927-28, Germany already owned a few airplane types which it would have been very difficult to throw into spins.* Airplanes with strongly warped wings, the tips of which have a smaller angle of attack than the central portion, were difficult to throw into a spin, since the maximum lift of the central wing portion and of the whole wing is exceeded sooner than the lift of the wing tips. Likewise unwarped rectangular wings, the camber of which does not decrease toward the tips, are still later-

*Airplanes which are difficult to throw into spins cannot easily recover from this attitude. The fact that it is hard to make them spin is attributable to deficient action of the movable tail surfaces, which also unfavorably affects the recovery.

ally stable at large angles of attack since, owing to the reduction in the effective angle of attack at the wing tips, they resemble warped wings aerodynamically.

Experience has shown that even very positively staggered airplanes are difficult to bring into autorotation. This seems to be due to the fact that, owing to the interference of greatly staggered wings, the maximum lift value is increased, while the decrease in lift for angles of attack increasing beyond the maximum lift value is only small. To be sure, these greatly staggered types were always provided with slotted ailerons. No definite statement can therefore be made as to the extent to which the stagger is covered by the action of the slots. The action of the slots along the leading edge of the ailerons results in an increase of the maximum lift at the wing tips and especially in an extension of the aileron effect to larger angles of attack. However, the lift increment with closed aileron is small. The slight inclination to spin, evinced by the wings described above, seems nevertheless to be due chiefly to the stagger.

The fact that aircraft with wings of the described type do not have the same tendency to spin as other airplane types is rather accidental than attributable to any definite intention of the designer. As soon as suitable means of preventing the spin have been devised, transverse stability in stalled flight should be made compulsory, at least on all airplanes in use on public transportation lines. So long as spinning must be taken into the bargain as a necessary evil, only airplanes with satis-

factory spinning characteristics should be accepted, which are capable of recovering from a spin at a sufficiently high altitude. The so-called "flat" spin, from which scarcely an airplane seldom recovers, must be avoided. This spin occurs at very large angles of attack and with great angular velocity.

In 1927-28 important data were obtained on the causes of the flat spin, which enabled the designing of airplanes capable of avoiding this dangerous phenomenon. Flat spins are caused by the characteristics of certain wing sections and biplane arrangements, which are known to produce an unlimited range of autorotation with increasing angle of attack. These characteristics depend on the course of the lift curve at large angles of attack. A sudden drop of the lift, without prompt recovery at angles of attack larger than that of maximum lift, affords the possibility of a flat spin. If, on the other hand, there is a prompt recovery of the lift at further increasing angles of attack, the range of autorotation is confined to specific angles of attack. Flat spins then become impossible.*

In the year this report was written, the spinning characteristics were found to be greatly affected by the position of the C.G. Flat spins occur when the C.G. is located far aft (40 to 45% of the chord). With the C.G. in a more forward position of at most 33% of the chord, the spinning characteristics involve no risk. As already mentioned, stability requirements are favor-

*See Bryant and Gates, "The Spinning of Aeroplanes," Journal of the Royal Aeronautical Society, July, 1927.

ably met by a C.G. located far forward. With particular reference to the spinning characteristics, the C.G. should in no case be located more than 33% of the wing chord from the leading edge.*

With a C.G. located far aft, the stabilizer should be highly lift-producing, in order to keep the airplane well balanced about the lateral axis in normal flight. In this case, however, there is danger that the maximum lift produced by the tail surfaces will be exceeded at large angles of attack and that the airplane will then become tail-heavy, owing to the sudden decrease in the lift of the tail surfaces. At the same time there is a loss in the elevator efficiency, owing to the separation of the flow on the horizontal tail surfaces. The airplane therefore stalls automatically and simultaneously loses its controllability. Besides, in stalling the wing, the downwash is flattened and the angle of attack at which the air flows against the tail surfaces is further increased, thus increasing the stall. This is another reason why it is dangerous to locate the C.G. too far aft. However, even with the C.G. in the normal position, the stabilizer is often set at large angles, either because the pilot chooses to have large nose-heavy moments for recovery from spins or as a result of faulty balance in spite of a correct location of the C.G. An upper limit should therefore be set for adjusta-

*The same information regarding the influence of the position of the C.G. on the spinning characteristics was obtained at about the same time in America. See Aviation, May 30, 1927, and July 18, 1927.

ble stabilizers. An airplane cannot be considered airworthy when, in order to achieve moment balance, its stabilizer is set at a high-lift angle.

Moreover, the importance of the damping action of the vertical tail surfaces during a spin was recognized. With decreasing inclination of the airplane to the horizon during a spin, the lateral angle at which the air strikes against the vertical tail surfaces gradually increases, so that the latter damp the rotation about the vertical axis. The excessive angular velocity of spinning airplanes can be reduced by increasing the size of the vertical tail surfaces. If, as mentioned above, there remains a tendency to respond to the rudder in stalled flight, the rotation during a spin can be stopped by it and the airplane can recover from the autorotation in spite of a fully deflected elevator. It is even possible, during a spin, to change the direction of rotation by deflecting the rudder. Since the ability to change the direction of rotation in a spin is an absolute proof of adequate rudder efficiency and of satisfactory spinning characteristics, proof of such ability is required of stunting airplanes.

An airplane is brought out of a spin by a downward deflection of the elevator, which brings the wing back to its normal position of flight. A good downward action and especially sufficient downward deflection of the elevator are essential. When the airplane comes out of the spin, it is in a rather steeply in-

clined gliding position. Many types require considerable altitude in order to resume level flight. Some accidents were due to the fact that the airplanes, although they had recovered from the spin, did not have time to resume level flight. Therefore, stunting airplanes must respond quickly to the controls in leveling off.

No reference is made in this report to the design of the pilot's seat, the location and arrangement of the controls, and to safety belts, although these greatly affect the pilot's comfort and his control of the airplane and consequently his safety.

Problems for the 1928-29 Flight Tests

In the year of the present report, tests dealing with flight characteristics had progressed so far that all the factors involved could be clearly defined and individual airplane types could be correctly judged. For 1928-29 the D.V.L. has set itself the task of developing methods and instruments for the numerical determination of airplane characteristics, which can furnish useful data for the designer and the theorist. It will always be necessary to verify, in actual flight, theoretical conclusions regarding flight characteristics. Measurements may afford information on some specific point of the behavior of an airplane, but only the judgment of the pilot can give a comprehensive idea of its general characteristics. In other countries, where the determination of airplane characteristics had, to a certain ex-

tent, been developed earlier than in Germany, test results are regarded as only supplementary and confirmatory of the statements made by the pilot. The further development and refinement of flight tests according to the many requirements of actual flight will therefore constitute the main task of the flight section of the D.V.L. in 1928-29.

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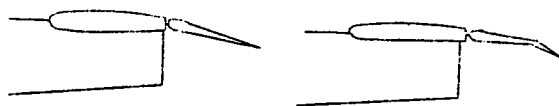


Fig.1 Changing the balance by bending the elevator.

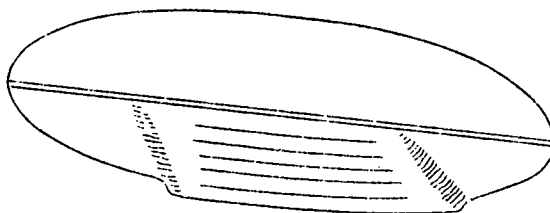


Fig.2 Changing the balance by warping the elevator.

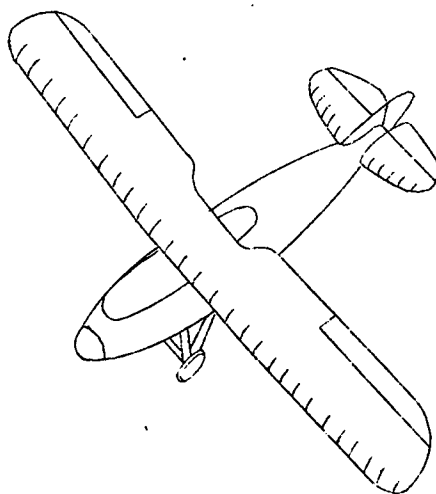


Fig.3 Balance variation by decreasing the downwash in center of wing.

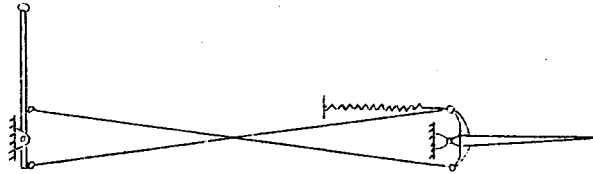


Fig.4 Changing the balance by providing the controls with a tension spring.No reduction in the control efficiency was observed.

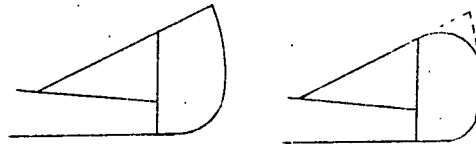


Fig.5 Reduction of the control forces by rounding off the contour of the rudder.

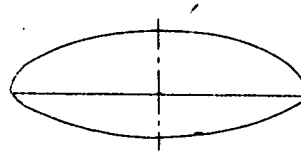


Fig.6 Influence of the outline of the elevator on its efficiency.The efficiency of elevators whose chords were greatly reduced laterally,was absolutely inadequate.

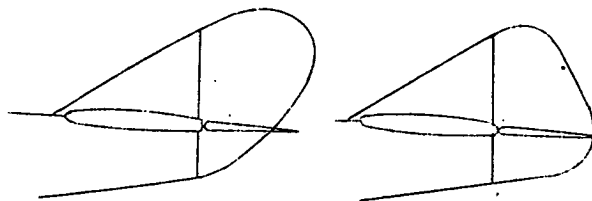


Fig.7 Improvement of the rudder effect at large angles of attack. Owing to the shielding of the elevator by the stabilizer, the left tail group produced only a small effect at large angles of attack. The efficiency at large angles of attack was improved by changing its outline to the shape shown on the right.



Fig.8 Effect of the aileron span. Ailerons extending over the whole wing span produce greater control forces and scarcely any greater efficiency than those covering only $\frac{2}{3}$ of the wing span.

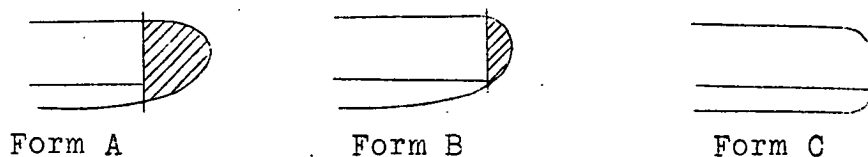


Fig.9 Influence of the wing tip shape on the ailerons. Wing model A produces poor aileron effects, since rotations about the longitudinal axis are strongly damped by the wing portion which extends beyond the aileron. This damping effect is reduced by an extension of the aileron outward, as shown by model B. The best results are obtained with model C, which has ailerons reaching to the wing tips.